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by

A.V. Petrov

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Procurement Executive, Ministry of Defence
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SOME FEATURES OF FLOW PAST SLOTTED WINGS

(O NEKOTORYKH OSOBENNOSTYAKH OBTEKANIYA RAZREZNYKH KRYL'EV)

by

A. V. Petrov

Uchenye Zapiski, TsAGI, 8, 6, 119-124 (1977)

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AUTHOR'S SUMMARY

The results are presented of an investigation into the flow about a slotted wing for a wide range of variation in the maximum relative curvature of the slotted profile (f_{max} = 0.1 to 0.3), angle of incidence (α = 0 to 40^o) and Reynolds number (Re = 0.5 × 10^6 to 1.55 × 10^6).

Features of the development of viscous wakes behind elements of the slotted wing were apparent; the presence was discovered of local regions of return flow, both at the surface of the wing and beyond it within the wakes of the upstream elements. Changes are shown in the configuration of the regions of return flow depending on the angle of incidence, the angle of deflection of the double-slotted flap and on the Reynolds number. A relationship is established between the characteristics of the change in the lifting properties of the slotted wing and the development of regions of return flow.

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The flow in the vicinity of a slotted wing can have a complex structure, which is characterised by the presence of interacting boundary layers at the surfaces past which the flow occurs, and of viscous wakes mixing with regions of potential flow. As a result of this multilayer nature of the flow over a slotted wing, characteristics can be produced which do not appear in the case of flow past a non-slotted wing. In Ref 1, on the basis of visual investigations of the flow past a slotted wing, it was established that return flow would occur, under particular conditions depending on the maximum relative curvature of the slotted profile, the angle of incidence, and the Reynolds number. This return flow could occur not only in the vicinity of the surface of the wing (this being associated with the separation of the boundary layer) but also away from the surface of the wing, in which case the return flow is separated from the surface by a comparatively thin layer of non-separated flow (detached separation). The presence of one or other type of separated flow on the individual elements of the wing or on the wing as a whole is the essential ingredient, which limits the possibilities of obtaining high values of lift by the use of slotted mechanisation. To understand this requires a detailed study of the characteristics of flow past slotted wings and of the effect of flow regimes on their lifting properties.

The aim of this work is the investigation of flow structures above the upper surface of a slotted wing and in the wake for a wide range of variation in the maximum relative curvature of the profile, the angle of incidence and Reynolds number. To this end, in a wind tunnel, a visual investigation was carried out, with the help of silk threads, into the flow pattern behind a wing having a two-element, slotted, drooping leading edge (elements I and II) and a double slotted flap (elements III and IV). The total pressure in the vicinity of the upper surface, in the wake of the wing and in the wake of flaps was also measured. A relatively wide gap between the flap elements (equal to 1% of the wing chord (Fig 1a) was chosen in order to ensure, as was established in preliminary tests, the highest value of the coefficient of lift. The investigation was conducted on models of a rectangular wing with end plates of elliptical form, giving an effective aspect ratio of 5:5 for a geometrical aspect ratio of 3. A change in the relative curvature of the profile was achieved in the main by deflecting the flap, the deflection of the leading edge of the wing being comparatively small. In experiments, the maximum relative curvature of the slotted profile (defined as the maximum curvature of the centre line of an equivalent continuous profile, the contour of which encompasses the contour of the slotted profile) varied from $\bar{f}_{max} = 0.1$ for the initial profile with non-deflected mechanisation to $\bar{f}_{max} \approx 0.3$ for the maximum angles of deflection of the flap and the leading edge of the wing, which were studied.

In order to visualize the flow at the surface of the wing and beyond it, silk threads were used. These were glued both to the upper surface of the wing and to profiled rods set up along the normal to the surface, at a section situated approximately in the middle of the semispan of the wing. Moreover, at this same section, a network containing silk threads was arranged behind the wing, making it possible to obtain a flow pattern in the wake of the wing.

In order to measure the total pressure in the vicinity of the upper surface and in the wake of the wing, a pitot rake was used, installed at the same section where visualisation of the flow was carried out. The results of measurements were presented in the form of a diagram showing the variation in the pressure coefficient ($\bar{p}_0$) with the height of the tube (y) above the surface of the wing. The pressure coefficient $\bar{p}_0 = (p_0 - p_\infty)/q_\infty$, where p_0 is the total pressure measured for an individual tube of the rake, and p_∞ and q_∞ are the static and dynamic pressures of the flow in the wind tunnel respectively.

Experiments were carried out for a range of angles of incidence $\alpha = 0 - 40^{\circ}$ and for wind speeds of $V_\infty = 15$, 25 and 45 m/s corresponding to Reynolds numbers $Re = 0.52 \times 10^6$; 0.86×10^6 and 1.55×10^6, based on the wing chord (which was equal to 0.5 m).

The visual investigation of the flow, and measurements of the total pressure head in the vicinity of the slotted wing, m. it possible to establish the following characteristics of the flow past it. For small values of the relative curvature of the profile ($f_{max} = 0.1$ to 0.15), the flow past the slotted wing is practically non-separated until large angles of incidence ($\alpha = 25$-30°) are involved. In this flow regime, experimental values for the lift coefficient of the wing are, over a wide range of angles of incidence, close to calculated figures obtained using a potential flow method[2] (curve 1, Fig 1b, where the broken lines indicate the calculated variation of C_L with α).

When the value of the angle of incidence is sufficiently large ($\alpha \geqslant 20$-30°) or for large values of the relative curvature of the profile ($\bar{f}_{max} \geqslant 0.15$), there arises, in the flow above the trailing part of the wing, a region of return flow (Fig 2a). At the same time however, non-separated flow is maintained directly at the surface of the wing and of the deflected flap. This region of return flow, which is separated from the surface of the wing by a comparatively thin layer of non-separated flow, and known as detached separation, spreads with increase in the angle of deflection of the flap and in the angle of incidence (Fig 2b).

The process of formation of detached separation above the wing, with the flap deflected by a large angle ($\bar{f}_{max} \approx 0.28$) can be followed by considering the variation of $\bar{p}_0$ with y , illustrated in Fig 3, where the shaded areas indicate regions of return flow. For small angles of incidence ($\alpha = 0$-10°) of a slotted profile of large curvature, the usual separation of flow from the flap surface is encountered (region A, Fig 3a). With increase in the angle of incidence, the region of separation adjacent to the flap surface decreases. At the same time, in the vicinity of the trailing part of the wing, there arises a broad region of detached separation extending to a distance equal to 0.75 to 1 chord behind the trailing edge of the wing (region B, Fig 3b).

For large angles of incidence ($\alpha \approx 35^{\circ}$), the separation of flow directly at the surface of the wing is completely eliminated. However, there is a widening of the local regions of return flow found in the flow behind the leading edge elements and, behind the basic part of the wing, the region of detached separation gradually moves towards the leading edge of the wing (Fig 3c).

At sufficiently large values of the angle of incidence, separation of flow from the leading edge of the wing occurs. At this point the region of detached separation expands, and moves forwards, while non-separated flow is maintained directly at the surface of the slotted wing (except in the case of the surface of element 1 of the leading edge (Fig 2b, Fig 3d)). This flow regime is accompanied by a sharp decrease in the lift coefficient of the slotted wing and corresponds to the stall of conventional single aerofoils (*cf* Fig 1b).

The value of the 'stalling' angle of incidence(associated with the occurence of flow separation from the leading edge of the wing and with a widening of the region of detached separation) decreases with increase in the angle of deflection of the flap and increases with an increase in the angle of deflection of the leading edge of the wing and in the Reynolds number. Thus, for example, while for a flow rate in the wind tunnel corresponding to a Reynolds number $Re \simeq 0.5 \times 10^6$, separation of flow from the leading edge of the wing occurs at $\alpha \approx 30^o$, for $Re = 1.55 \times 10^6$, this phenomenon occurs only at $\alpha \approx 40^o$. The dimensions and configurations of the region of detached separation for below the stall (as shown by visual investigations and measurements of the total pressure head) change comparatively little with a change in the Reynolds number over the range $Re \approx (0.8 \text{ to } 1.5) \times 10^6$. However, as the Reynolds number falls to 0.5×10^6, there occurs a marked widening of the region of detached separation (Fig 4).

The occurrence of either the usual or the detached separation has a profound effect on the lifting properties of the slotted wing causing the significant reduction in the measured lift coefficient of the slotted wing with a profile of large relative curvature ($\bar{f}_{max} \approx 0.28$) compared with calculated values of the coefficient C_L obtained according to potential theory (*cf* curve 2 in Fig 1b).

The creation, in the flow, of regions of return flow separated from the wing surface by a layer of non-separated flow, is a characteristic of multilayer flow consisting of - (i) regions of potential flow (ii) boundary layers at the surfaces past which flow occurs (iii) of viscous wakes behind elements of the slotted wing. Wakes formed behind individual elements of the slotted wing can either be entrained into the main flow by viscosity or, in contrast, under the influence of adverse pressure gradients, produce a return flow region (*cf* Fig 3b,B). Hence, depending on the size of, and changes in, the pressure gradient, the minimum velocity in the wake can vary in value and direction, as a result of which regions of return flow can subsequently occur in the flow.

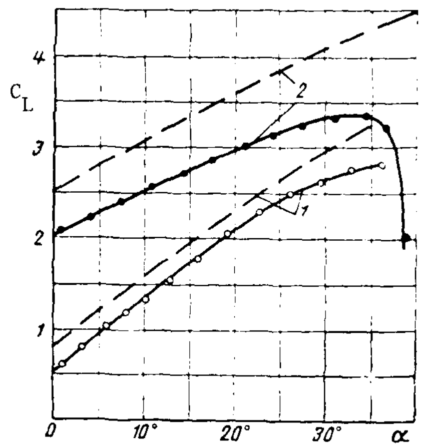
The presence of zones of reverse flow beyond the surface of the slotted wing may be associated not only with the development and destruction of viscous wakes behind the elements of the high lift system. A flow of this type can also exist when separation of flow from the surface of the slotted wing is involved. In this case, a region of highly developed separation arising at one of the elements of the slotted wing can be separated from the remaining elements of the wing by a comparatively thin layer of non-separated flow formed by jets of air passing through the slots of the slotted wing. In the presence of such a type of flow, for example in the case of separation of flow from the leading edge of the wing, there occurs, as indicated above, a sharp reduction in the lift, in

spite of the maintenance of non-separated flow at a large part of the wing surface. Instances are known of a reduction in the efficiency of slotted flaps under conditions where observation provides evidence of the non-separated character of the flow directly at the surface of the flap[3]. This circumstance must be considered in the designing and experimental investigation of wings having a high lifting capacity and slotted mechanisation.

REFERENCES

No.	Author	Title, etc
1	A.V. Petrov	Nekotorye tipy otryvnogo obtekaniya razreznykh kryl'ev. (Some types of separated flow past slotted wings.) Uchenye Zapiski, TsAGI, <u>8</u>, 2 (1977)
2	G.A. Pavlovets	Metod rascheta obtekaniya ideal'noi neszhimaemoi zhidkost'yu krylovogo profilya proizvol'noi formy s mekhanizatsiei. (A method for the calculation of an ideal incompressible liquid past a wing profile of any shape, with slotted high lift devices.) Tekhi. otchety TsAGI, <u>349</u> (1969)
3	J.J. Cornish	Some aerodynamic and operational problems of STOL aircraft with boundary-layer control. *Journal of Aircraft*, <u>2</u>, 2 (1965)

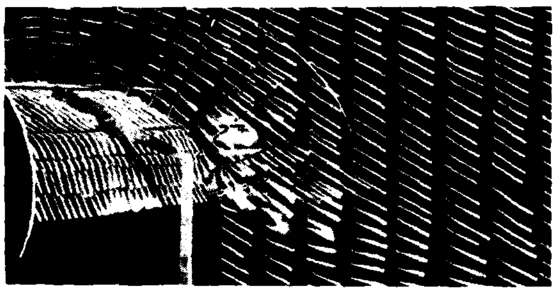
(a)



(b)

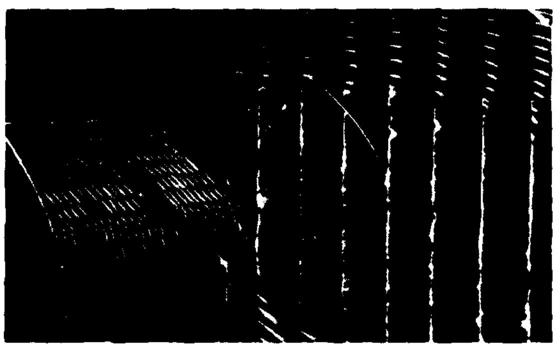
Fig 1

$\bar{f}_{max} \approx 0{,}18$; $\alpha = 20°$



(a)

$\bar{f}_{max} \approx 0{,}28$; $\alpha = 40°$



(b)

Fig 2

Figs 3&4

$\bar{f}_{max} \approx 0,28$; V = 45 M/S(PC); $\alpha = 10^{\circ}$

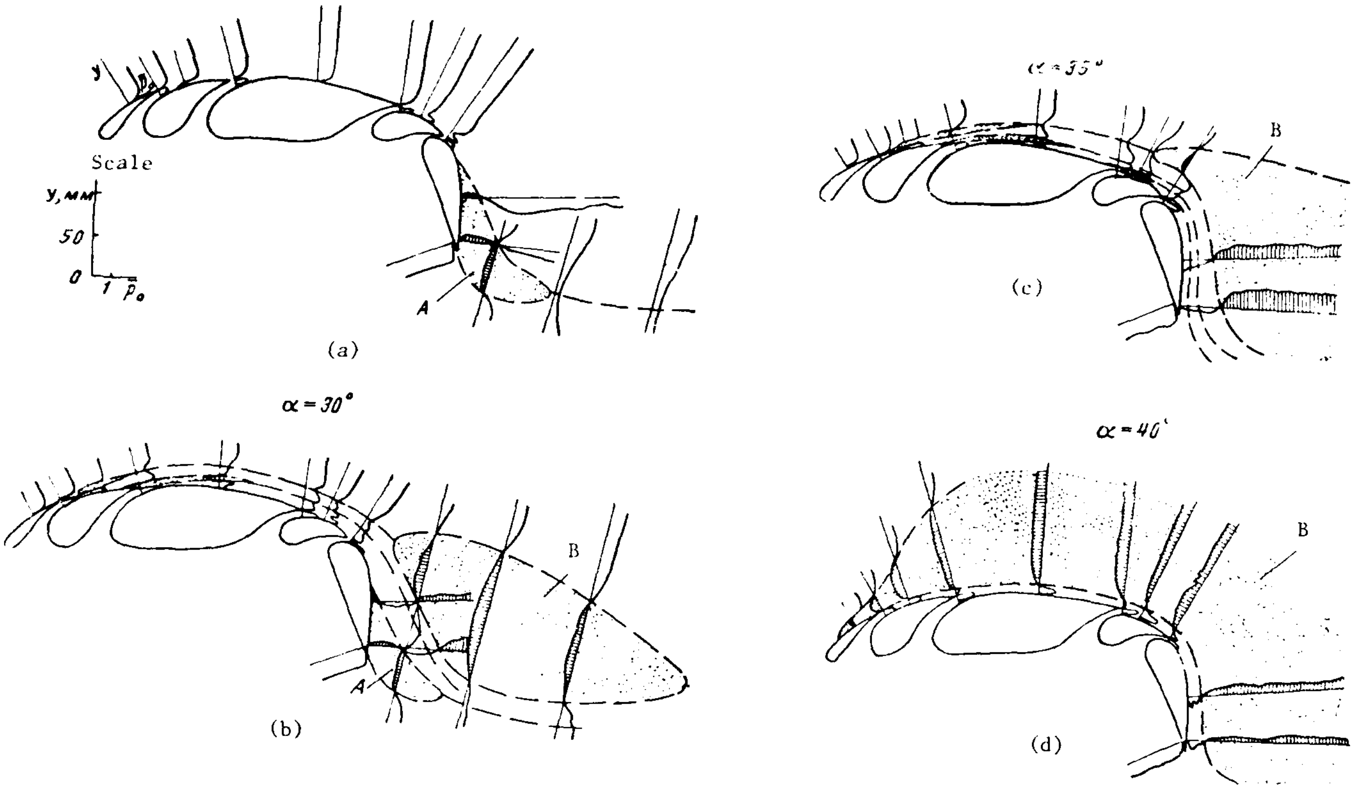


Fig 3

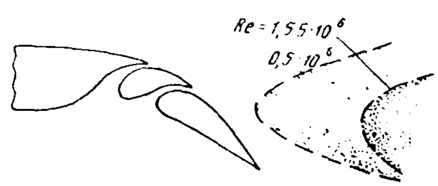


Fig 4

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